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PRELIMINARY DATA REGARDING THE COPPER CONTENT FROM THE ARAMA OLTULUI SULPHIDE HORIZON (BALAN NAPPE - EAST CARPATHIANS)

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KEY WORDS: Tulghes Group, Sandominic Nappe, Arama Oltului member, sulfide disseminations, statistics, variogram

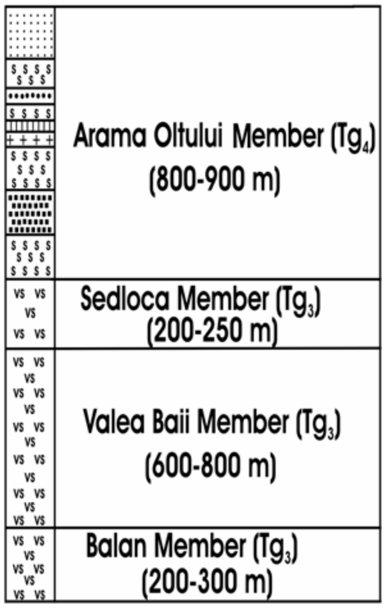
Introduction

In the southern part of the crystalline – mesozoic area of the East Carpathians, the Tg_3 and Tg_4 Cambrian formations of the Tulghes Group are found in Balan Nappe and Sandominic Nappe (Kräutner, Popa, 1973; Vâjdea, Anastase, 1975; Kräutner, 1989; Kräutner et al., 1992; Kräutner, 1994; Olaru, Apostoae, 1995; Kräutner, Bindea, 1995; Zincenco, 1995; Apostoae, 1998; Olaru, Apostoae, 2004; Olaru et al., 2005).

The mineralization, mainly represented by disseminated pyrite and chalcopyrite ores, is harmoniously interlaced with low grade metamorphites from Balan Nappe. Although researchers are currently exploiting only the mineralization situated at the level of Balan sulphide horizon (Tg_3 - Balan member), they have also investigated the economic potential of other mineralized layers (Tg_4 - Arama Oltului member: Arama Oltului sulphide horizon; Tg_3 - Sedloca member: the Sedloca sulphide horizon; Tg_3 - Valea Baii member: Salamas and Valea Baii sulphide horizons).

In Arama Oltului member, represented by sericite quartzites and sericite – chlorite- quartz schists, the acid and basic metamicroconglomerates and metavolcanics are individualized in the inferior part through sericite-chlorite schists with 2-4 levels of pyrite disseminations locally associated with chalcopyrite. (Fig. 1).

The Cu contents were calculated on the drill cores obtained from 20 vertical drillholes that intercepted the Arama Oltului sulphide horizon on an apparent thickness of 25 meters.



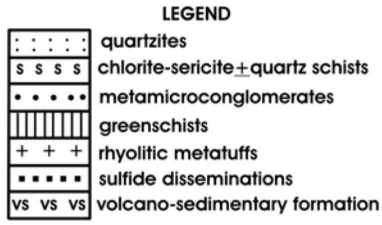


Fig. 1. Lithostratigraphic sequence of the Tulghes Group in the Bălan Nappe (not a scale)

Univariate statistics

The analyzed Cu contents are included into a large range of values, namely 25 - 2000 ppm (Fig. 2). The distribution according to classes of values (Fig. 3) indicates the characteristic of reduced Cu contents, 66,2 % of the content values being situated in the 25-250 ppm interval. Only 16,8 % of the content values are found the 250-1000 ppm interval and 17 % in the 1000-2000 ppm interval. The graphic from figure 4 describes the Cu contents distribution manner.

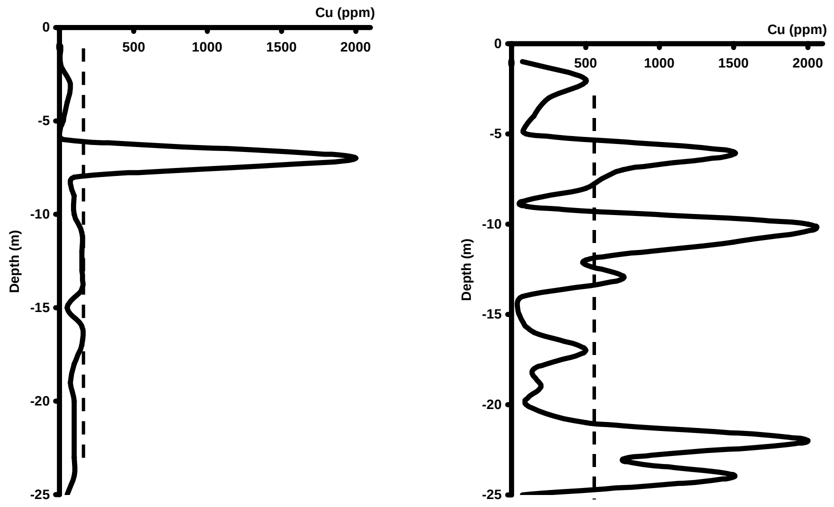
The clustering of points at low values and the tail extending toward the high values indicate that the Cu contents do not conform to a normal distribution. Also, the departure from a straight line at lower values on the lognormal probability plot indicates that the data do not fit a lognormal distribution either.

The average values calculated for the Cu contents (Fig. 5) vary between 167 ppm (the drillhole 11) and 589 ppm (the drillhole 17). The graphic about the depth stages (Fig. 6) indicates a tendency of leveling the values of Cu medium contents.

The standard deviation, varying between 384,580 (F 11) and 711,114 (F18) (Fig. 5), describes the variability of the data values.

A positive skew with a tail of high values to the right is evident from the positive skewness (Fig. 7) that varies between 1,125 (F18) and 4,887 (F11). Kurtosis varies in larger limits (Fig. 6) and namely 0,153 (F13) and 24,226 (F11).

The degree of asymmetry is also supported by the coefficient of variation that is situated between 105,310 % (F17) and 230,564 % (F11) (Fig. 5). The values of the variation coefficient suggest the absence of a normal distribution (Isaaks, Srivastava, 1989; Armstrong, 1998).



a. b.

Fig. 2. Variation examples of the Cu content according to the depth: a drillhole 11; b. drillhole 17; **(** - - - - mean)

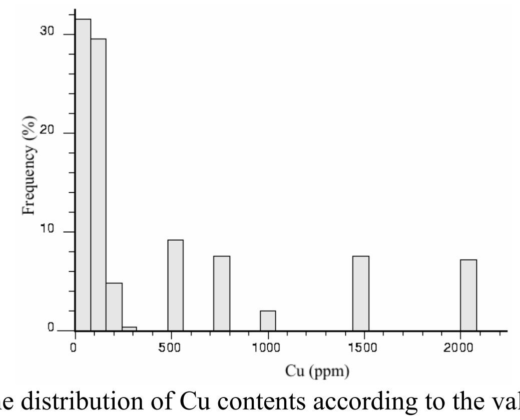


Fig. 3. The distribution of Cu contents according to the value classes

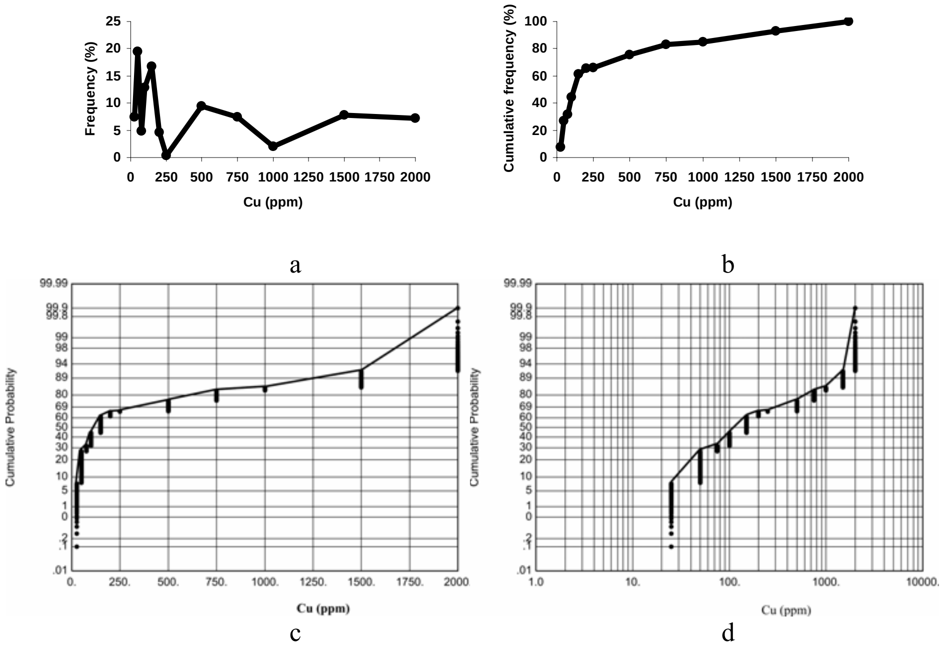


Fig. 4. The distribution of Cu contents : a . frequency plot; b. cumulative frequency plot; c. normal probability plot; d. lognormal probability plot

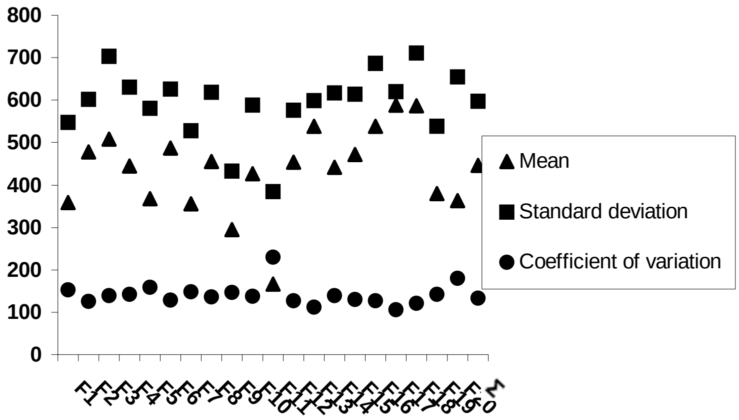


Fig. 5. Mean, standard deviation and coefficient of variation of the samples for each drillhole (F1...F20) and for all the drillholes (Σ)

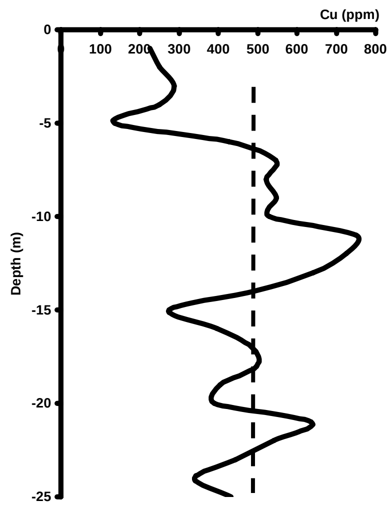


Fig. 6. The variation of average copper contents according to depth stages for all the drillholes (- - - - mean)

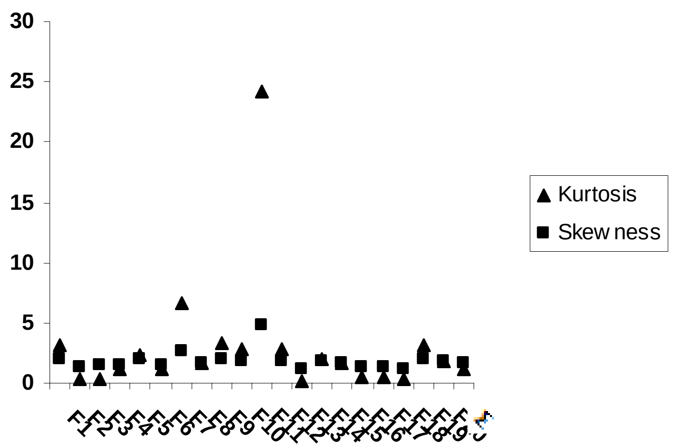


Fig. 7. Kurtosis and skewness of the samples for each drillhole (F1...F20) and for all the drillholes (Σ)

The median and the mode: the median and mode values for the Cu contents studies present a direct correlation (Fig. 8); moreover, in the case of nine drillholes (F2, F4, F6, F11, F12, F14, F15, F17, F19) the median and mode values coincide. If in general the values of the statistic parameters mentioned belong to the same scale of values, the drillhole no. 17 is distinguished through high statistical values, namely 500 ppm.

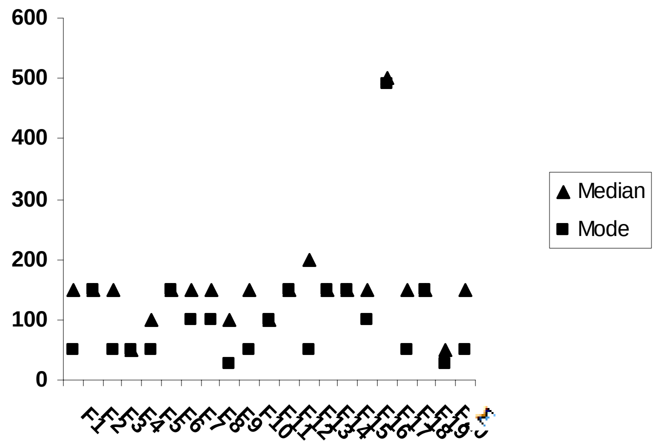


Fig. 8. Median and mode of the samples for each drill hole (F1...F20) and for all the drillholes (Σ)

The variograms

a) The average variogram

The average variogram (Fig. 9), that expresses the average of variograms drawn up for the Cu content from the drillholes, presents an increase for a distance of approximately 6 meters. Then, after reaching the sill, the graphic presents light oscillations. At approximately 21 m the average variogram value diminishes suddenly, which suggests the presence of a major variation of the Cu content.

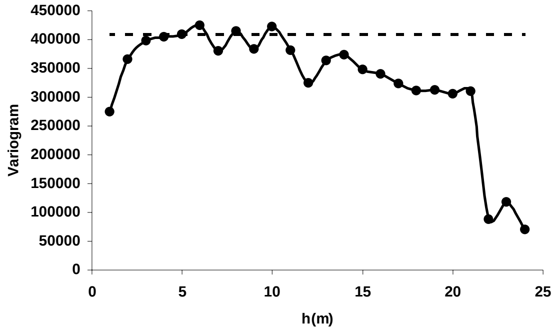


Fig. 9. The average variogram

b) The individual variograms

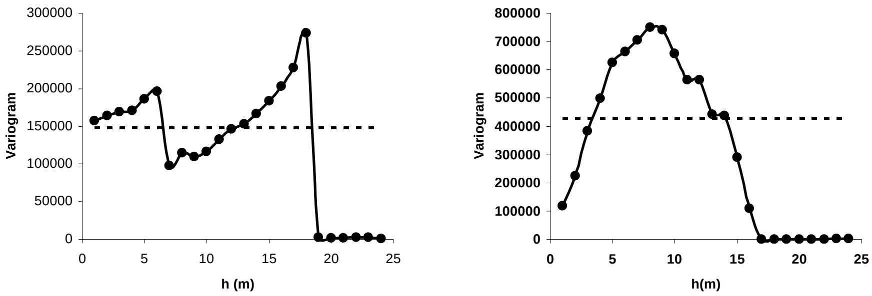
The aspect of some experimental variograms reflects the typical behavior for a certain distribution of the Cu contents in the lithological column of the drillhole studied.

An interesting situation appears in the case of the experimental variogram carried out for the Cu content from the drillhole 11 (Fig. 10a). This drillhole is characterized through the presence of the 2000 ppm Cu value, situated at 7 m from the drillhole opening. The other 24 meters of the lithological column of the drillhole present Cu contents oscillating between 25 ppm and 150 ppm (Fig. 2a).

When establishing the experimental variogram value, the percentage referring to the extreme value of 2000 ppm is different: thus, in the case of the first 6 points of the variogram, the 2000 ppm Cu value is calculated by two pairs, while from point 7 up to point 18 the value is present in the calculation of a single pair. These aspects explain the behavior of the experimental variogram between the points 6 and 7 and 18 and 19 respectively.

The experimental variogram drawn up for the Cu contents determined in the drillhole 20 (Fig. 10b) reflects the presence of a layer of schists where the Cu content is high (1000-2000 ppm), with an average value of 1600 ppm. In comparison, in the intervals 0-8 m and 14-25 m of the lithological column of the drillhole, the Cu content varies between 25 ppm and 100 ppm, with an average value of 37,5 ppm (the interval 0 - 8 m) and 64,6 ppm (the interval 14 - 25 m). This type of distribution of the Cu contents in the lithological column is reflected in the behavior of the experimental variogram graphic.

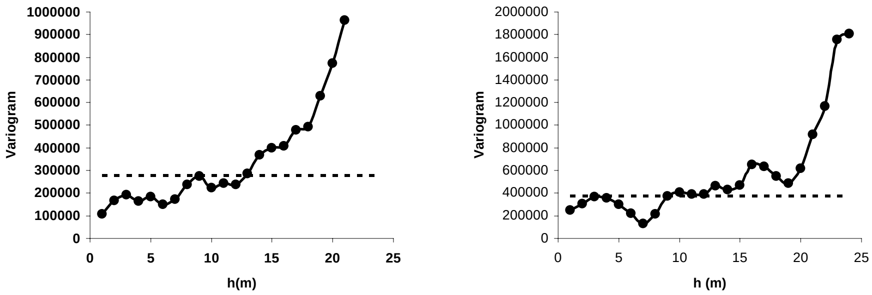
Thus, in the case of the first 8 points of the variogram, the number of value pairs comprising the high Cu contents calculations, increases from 6 pairs to 10 pairs. Starting from point 9 of the variogram and up to point 16 the number of value pairs decreases, calculating also the high contents of Cu from 9 pairs to 1 pair. This behavior explains the increase registered by the variogram graphic from point 1 up to point 8, followed by a slow decrease that is emphasized suddenly, starting with point 17 of the variogram.



a. b.

Fig. 10. a: variogram for drillhole 11; b: variogram for drillhole 20

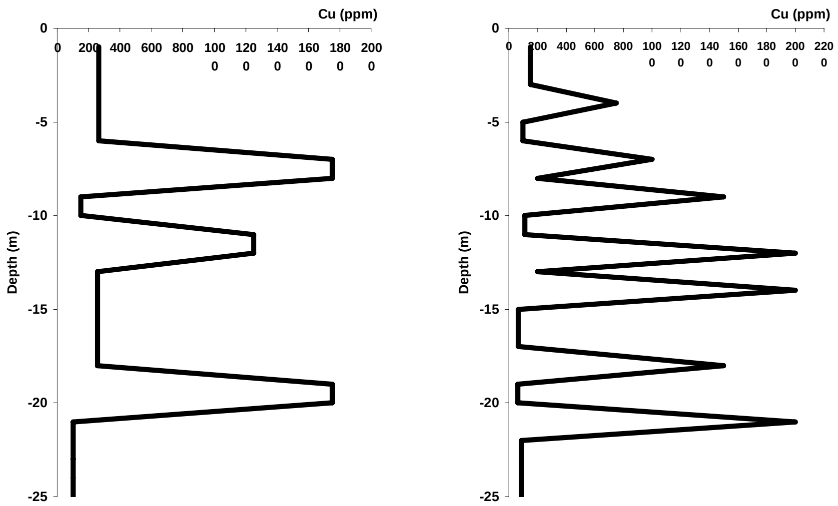
The allure of experimental variograms calculated for the Cu content from the drillholes 7 and 15 (Fig. 11a, b) reflects the presence of drillholes in the inferior part, in the interval 23-25 m, of two samples with high Cu contents (2000 ppm). Moreover, in the case of drillhole 15, Cu contents were also discovered in the interval 16-18 m, contents whose average is of 1500 ppm. The participation of high contents to the calculation of experimental variogram points generates the rising aspect of the graphic.



a. b.

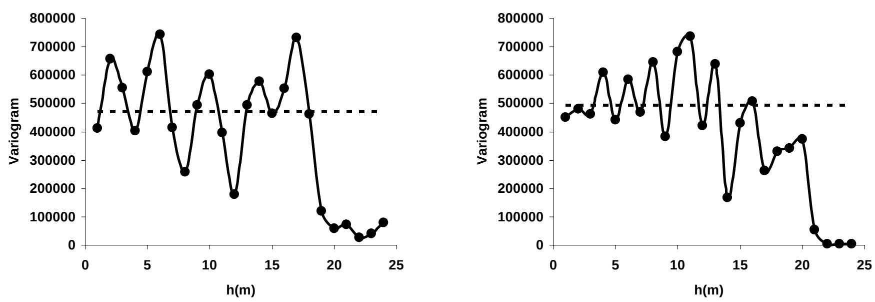
Fig. 11. a: variogram for drillhole 7; b: variogram for drillhole 15

In the case when the high contents alternate with the small Cu contents (Fig.12), the experimental variogram form is influenced by the differences in value between the Cu contents and by the position held by the samples with high content values compared to those with reduced content values (Fig. 13 a, b). The absence of high values of Cu content in the calculation of the variogram value in a certain point, leads to the sudden decrease of the experimental variogram values.



a. b.

Fig. 12 . The variation of Cu content according to the depth stages: a. drillhole 16; b. drillhole 3

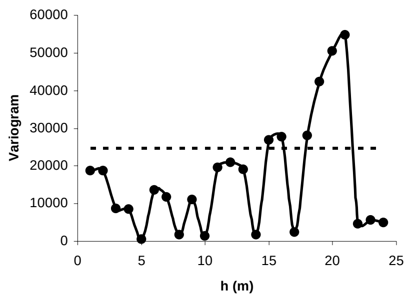


a. b.

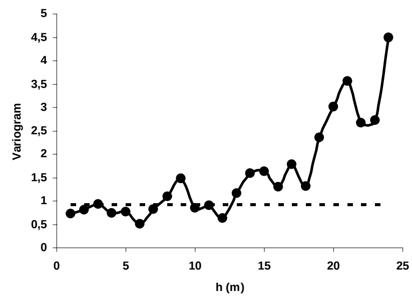
Fig. 13. a: variogram for drillhole 16; b: variogram for drillhole 3

The problem of outliers

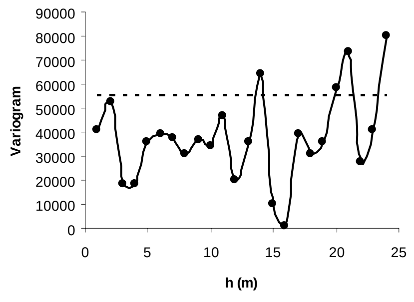
In the case when we investigate the economic potential of a mineralized horizon, the richest samples can make an orebody payable. As they are not preferentially located, removing the extreme values and thus perturbing the variogram, could be dangerous because the variogram obtained based on the content values remained can be meaningless. Thus, in the lithological columns of the drillholes studied, the high Cu contents that can be considered as outliers (beginning from 1000 ppm), are distributed on the whole length of the interval analyzed , without noticing preferential levels (Fig. 2, Fig. 6, Fig. 12). The individual variograms obtained after excluding the outliers (Fig. 14 a, b, c) do not present a better structure , but they are a little smoother compared to the initial individual variograms.



a.



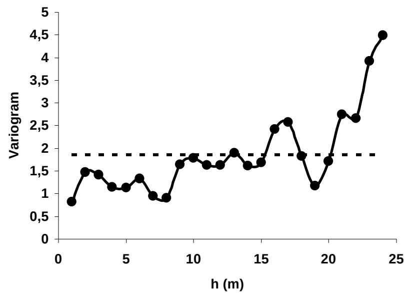
b.



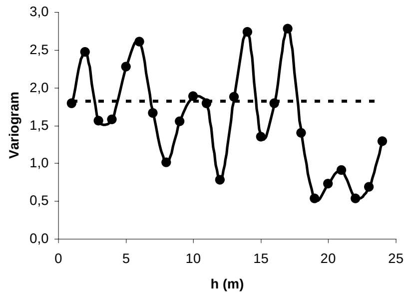
c

Fig. 14. Variograms without outliers: a: hole 3; b: hole 7; c: hole 16

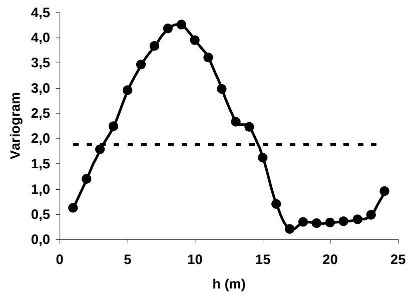
Another method used for reducing the impact of outliers on the variogram is the use of logarithmical values. The individual variograms of the logarithms (Fig. 15 a, b, c) do not show a better, very stable structure that could facilitate the ulterior interpretations.



a.



b.



c

Fig. 15. Variograms for the logarithms: a: drillhole 15; b: drillhole 16; c: drillhole 20

Conclusions

- in the low grade metamorphites from the Arama Oltului member of Balan Nappe belonging to the Tulghes Group, 2-4 levels of pyrite disseminations are located, locally associated with chalcopyrite;
- the Cu contents were evaluated on drill cores of 1 m length obtained by digging 20 vertical drillholes that intercepted the Arama Oltului sulphide horizon on an apparent thickness of 25 meters;
- the Cu contents vary between 25 and 2000 ppm, the average value oscillating between 167 ppm and 589 ppm;

- statistics indicate the fact that the Cu contents do not conform to a normal distribution and the presence of a lognormal distribution is suggested;
- the average structure of the raw variables, which was computed on 20 vertical drillholes, appears to be poorly defined;
- the individual variograms reflect the distribution of Cu contents along the lithological column of drillholes;
- the variograms obtained after excluding the outliers do not show a better structure, but they are lightly smoother;
- the structure of the variograms of logarithmic variables is more stable, and thus better known.

REFERENCES

APOSTOAE L. (1998) – *Geological, Petrographical and Mineralogical Study of Metamorphic Formation in the Bălan Area (Eastern Carpathians)*. Ph.D. Thesis (in Romanian). „Al. I. Cuza" University, Iaşi.

ARMSTRONG MARGARET (1998) – *Basic Linear Geostatistics*. Elsevier.

DEUTSCH C.V., JOURNEL A. G. (1998) – *GSLIB Geostatistical Software Library and User's Guide*. Second Edition. Oxford University Press.

ISAAKS E. H., SRIVASTAVA R. M. (1989) – *An Introduction to Applied Geostatistics*. Oxford University Press, Oxford.

KRÄUTNER H. G., POPA GH. N. (1973) –*Succesiunea litostratigrafică şi tectonica Cambrianului inferior epimetamorfic (seria de Tulgheş) din regiunea Bălan – Carpaţii Orientali*. D.S., LIX (1972), p. 251-278, Bucureşti.

KRÄUTNER H. G. (1989) – *Depositional models for the stratiform base metal and pyrite ore deposits of the East Carpathians*. D.S.Inst.Geol.Geofiz., 74/2 (1987), p. 47-68, Bucureşti.

KRÄUTNER H. G., UDRESCU CONSTANŢA, GAFTOI FILOFTEIA (1992) – *Sulfur isotopes and trace elements in copper ores and pyritic schists from Bălan (East Carpathians)*. Rom. J. Mineral Deposits, 75, p. 1-29, Bucureşti

KRÄUTNER H. G., BINDEA G., VOICU G., RUNCEANU M., MUNTEANU M., LUPULESCU M., LUPULESCU A., VAIDA MARIOARA (1992) – *The metamorphic rocks of the Gîrbova massif* (in Romanian). Rom. J. Petrology, 75, p. 161-181, Bucureşti.

KRÄUTNER H. G. (1994) – *Pre-Alpine terranes in the Romanian Carpathians*. Rom. J. Petrology, 75, supp. 1, p. 31-31, Bucureşti.

KRÄUTNER H. G., BINDEA G. (1995) – *The Ditrău Alkaline Intrusive Complex and its Geological Environment*. Rom. J. Mineralogy, 77, supp. 2, p. 1- 44, Bucureşti.

OLARU L., APOSTOAE L. (1995) – *La présence de quelques acritarches dans le groupe de Tulghes (Tg_3 – la zone de Bălan, Carpates Orientales)*. An. St. Univ. „Al. I. Cuza" Iaşi, Geol., tom XL-XLI, p. 227-282, Iaşi.

OLARU L., APOSTOAE L. (2004) – *Arenigian Chitinozoans from the Tulghes Group, Upper Formation from Bălan zone, Eastern Carpathians*. Acta Palaeontologica, IV, p. 299-314, Cluj-Napoca.

OLARU L., APOSTOAE L., APOSTOAE LILIANA (2005) – *Contributions à l'étude palynologique de la formation supérieure (Tg_4) de la région de Bălan (Carpates Orientales*). An. St. Univ. „Al. I. Cuza" Iaşi, Geol., tom XLVIII, p. 133-159, Iaşi.

SINCLAIR A. J., BLACKWELL G.H. (2002) – *Applied Mineral Inventory Estimation*. Cambridge University Press.

VÂJDEA ELEONORA, ANASTASE S. (1975) – *Absolute dating by the method of common lead of some deposits connected with the crystalline massifs of the East Carpathians (Romania*). Proc. 10th Congr. Carp. Balk. Geol. Assoc., IV, p. 253-260, Bratislava.

ZINCENCO D. (1995) – *Chronostratigraphic Scale of the Pre-Permian Metamorphites and Granitoids from Romanian Carpathians*. Proc. XV Congr. Carp. Balc. Geol. Assoc., Geol. Soc. Greece, Sp. Publ., 4, p. 647-652, Athens.